Portable Positron Measurement System (PPMS): Automated, nondestructive inspection system characterizes atomic-level properties

The quest for agility, especially in optimizing properties during material manufacturing, has been elusive in product manufacturing, until now.

Researchers at Idaho National Laboratory have developed the Portable Positron Measurement System or PPMS, which non-destructively tests materials at the atomic level throughout the production process.

PPMS provides feedback and control capabilities during high-temperature fabrication, solidification and heat treatment. It uses photon-induced positron annihilation to ascertain material properties.

Until now, engineers relied upon nondestructive and destructive testing of completed product samples which has yielded unacceptable failure rates. Simultaneous manufacturing and monitoring were prevented by the complex interplay of temperature, time at temperature, cooling rates, heat treatments, and strain reduction during fabrication and heat treatment.

“Automated and portable for in-situ operation, PPMS continuously measures subnanoscale lattice structures and dislocation densities that affect material properties during critical formation and heat-treatment steps," said INL researcher Doug Akers.

Initially developed to optimize the production of high-quality semiconductor and scintillation detector materials for national security, this technology uniquely characterizes metallic and nonmetallic materials during material formation processes involving melt, solidification, and/or heat treatment.

“PPMS works on the principle that the decay properties of positrons injected into a material depend on atomic electron densities, so an analysis of the gamma rays emitted reveals atomic-level information about the material,” Akers said.

“Previous processes permitted characterization to a depth of 10-50 microns of the material surface. INL’s process reaches to 10 centimeters into the material, allowing positron depth profiling and volumetric characterization of materials not possible before.”

Small, portable, and automated, PPMS uses radioisotopes or a linear accelerator to induce positrons in a material during production, even in materials being formed in furnaces at 1,600º C. PPMS provides data on critical properties of the material, such as lattice structure changes, dislocation density, pore size/density, and strain.

An automated scanning system is used to profile the positron response at various locations in the material to evaluate homogeneity and the development of multiple phases or inclusions during the process.

Features of the system include:

- Fully automated data acquisition and analysis.
- Suitable for nonphysics or nontechnical users.
- System performance monitoring with control charts.
- Material-specific, preset, parametric-analysis variables.
- Continuous data acquisition-analysis mode.
- Easily modifiable for continuous QA applications.

PPMS surpasses all current formation processes by:

- Monitoring material properties throughout the formation process,
- Operating in production environments, instead of post-production situations,
- Functioning in high-temperature environments, as high as 300 to 1,600º C,
- Recording continuous feedback data for production control, and
- Presenting fully automated quality analysis during production.

PPMS is very easy to use and requires minimal operator training. Best of all, it offers a low product cost and maintenance expenditures.

PPMS solves the mystery of knowing the material condition of a product as it is formed. The ability to know this offers exciting changes to material production and product quality.